Beam-Induced Structure Characterization in the Helium Ion Microscope

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Focused ion and electron beams are versatile tools for the observation and creation of nanostructures. The ability to create structures is greatly enhanced by the process of beam induced deposition and etching. Such nano-scale structures are useful in several applications, such as electrical devices patterned on the nanoscale, photonic devices, basic nanoscience research, and the like. The helium ion microscope (HIM) demonstrates a sub-nanometer spot size and unique beam-sample interactions, making it a candidate for sculpting smaller features[1],[2]. Thus one should seek recipes to minimize feature sizes, maximize compositional purity, or optimize conductivity or resistivity. Determination of these optimum properties of deposited or etched features, however, requires searching over a large parameter space with many variables.

In this work we report on the use of a Design of Experiments approach[3] to characterize the deposition of conducting structures (from $MeCpPt(IV)Me_3$ precursor) and insulating structures (from tetraethoxysilane, i.e. TEOS). The experiments vary four primary beam scanning parameters in a HIM (Orion Plus; Carl Zeiss NTS, Peabody, MA) equipped with a gas injection system (OmniGIS; OmniProbe, Dallas, TX): beam current, pixel step size, dwell time, and pattern repeat number. The "DOE PRO XL" software package was utilized for computer aided experimental design. In some cases a secondary experiment varies beam focus and beam energy. The gas flow conditions are held fixed for simplicity. The critical parameters optimized are: width of deposited lines, width of gaps between lines, chemical composition, deposition rate, and electrical resistivity. AFM and HIM are used for width and height measurements, EDS for composition analysis, and 4-probe analysis for resistivity. By using properly designed patterns, observations can be made of any cross-talk between developing features (Figure 1).

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[1] P.F.A. Alkemade, et al., Microsc Anal, 24(7), 5 (2010).
[2] D. Maas et al., Proc. of SPIE Vol. 7638, 763814
[3] C. Sanford et al., J Vac Sci Technol B 27(6), 2660 (2009).

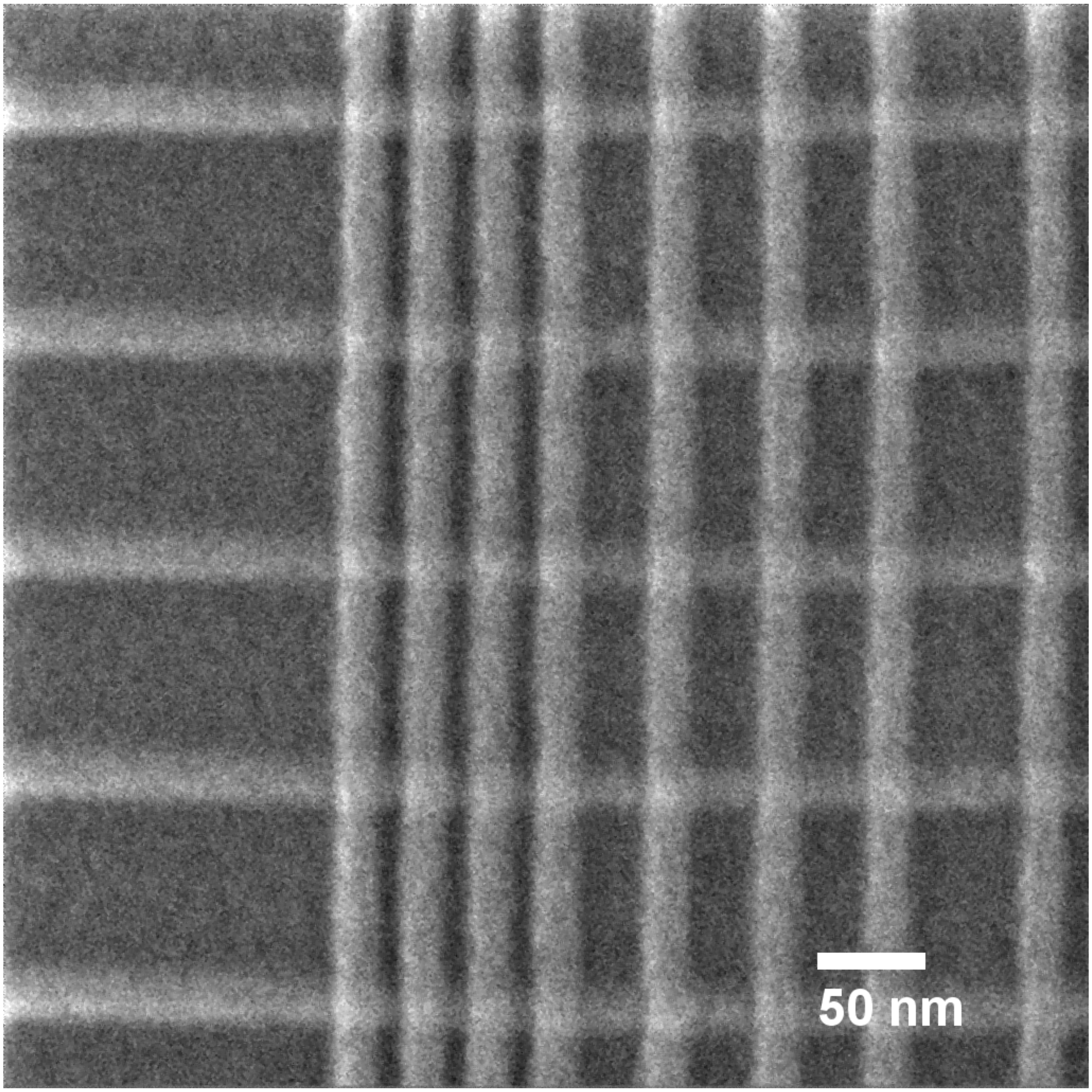

Figure 1: Variable pitch line grating pattern deposited in HIM from platinum precursor. Line width, gap width, and cross-talk effect measurements can all be made from this structure. Left-most vertical lines approximately 18 nm wide, with 11 nm gaps.